Guest Editorial Special Issue on Intelligent Control Through Neural Learning and Optimization for Human–Machine Hybrid Systems

WITH the rapid development of science and technology, in order to realize intelligent control for human–machine hybrid systems, research scholars have studied a large number of learning approaches. However, the problem that we need to further consider is ensuring the control stability while realizing the optimal performance of human–machine hybrid systems.

The aim of this special issue is to explore machine intelligence with natural interaction and learning capabilities. Special attention should be given to how to construct a cognitive computing framework with an adaptive-memory-autonomous learning dynamic interaction loop, study the reinforcement learning theory of hybrid intelligence systems, and propose a novel hybrid theory and the methods of brain–computer fusion systems. This includes, but is not limited to, autonomous underwater vehicles (AUVs), micro aerial vehicles (MAVs), exoskeleton robots, multiagent systems (MASs), unmanned aerial vehicles (UAVs), and underactuated surface vessels.

This special issue received many articles on intelligent control from different countries, of which 14 articles contributed significantly and were accepted for publication in this special issue. The contents of these 14 articles are briefly described below.

AUV is a typical system with high nonlinearity, strong coupling, uncertain motion model, severe interference, and constrained inputs. Therefore, the tracking control problem of AUVs is a major scientific problem and is extremely challenging. Regarding the issues above, Wenjie Shi, Shiji Song, Cheng Wu, and C. L. Philip Chen present a model-free policy gradient algorithm via a hybrid actors-critics structure, where actors are used to generate a deterministic policy and critics are employed to approximate a cost function. Thus, the approach can realize high-level tracking accuracy and stable learning performance of AUVs. The availability and generality of the proposed strategy are demonstrated by the experiments on AUVs.

In order to address the tracking control problem of coaxial-rotor micro-aerial vehicles (CRMAVs) under highly complex conditions, Jinglan Li, Qinmin Yang, Bo Fan, and Youxian Sun propose a high-gain observer based on neural networks (NNs) for the challenge of unknown time-varying external disturbances and model uncertainties, so as to estimate online the unavailable states. In addition, the authors design an output feedback controller to deal with the tracking control problem of CRMAVs. Moreover, a large number of simulation results have demonstrated the trajectory tracking performance in terms of position and direction. MAVs can be used for low-altitude survey, aerial mapping, and environmental monitoring, the control problem research for MAVs, therefore, has a strong practical significance.

Exoskeleton robot is a wearable mechanical mechanism that combines sensing, control, information, fusion, and mobile computing. Zhijun Li, Junjun Li, Suna Zhao, Yuxia Yuan, Yu Kang, and C. L. Philip Chen develop a novel noninvasive control strategy based on brain–machine interface (BMI). Considering the constraint problem of exoskeleton robots in the human–machine-environment interaction, an adaptive controller based on the barrier Lyapunov function (BLF) is proposed to realize the trajectory tracking and solve the problem of less understanding of exoskeleton robots dynamic parameters. This work will promote the development of medical robots in the direction of intelligence, security, and preciseness.

Robots are multi-input–multi-output (MIMO) nonlinear systems with the dynamic characteristics of time-varying and strong coupling. Due to the inaccuracy of measurement and modeling, as well as the effects of load changes and external disturbances, it is impossible to obtain an accurate dynamic model in practice. Therefore, studying the control problem of uncertain robots has important theoretical and practical significance. Taking the two-DOF manipulator as an example, in order to solve the constraint problem of robot systems, Qing Guo, Yi Zhang, Branko G. Celler, and Steven W. Su construct a radial basis function (RBF) to obtain preliminary estimate model through the backstepping method. An adaptive NN control is proposed to online optimize the model and enhance the robustness of the system. Simulation and experimental results are carried out to demonstrate the control performance of the NN strategy.

The navigation technology of mobile robots is the hotspot and focus of the current research. With the deepening of navigation technology research, industrial AGV handling robots, intelligent vehicles, and defense technology research have made major breakthroughs. To solve the problem of nonrigid point set registration, Jiayi Ma, Jia Wu, Ji Zhao, Junjun Jiang, Huabing Zhou, and Quan Z. Sheng design a robust transformation learning approach and apply the approach

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presented in this article to learning motion flows between the image pairs of similar scenes for visual homing. A large number of experiments are presented to prove the feasibility of the proposed approach. The works provide a new idea for mobile robot navigation methods and have important practical significance.

In recent years, learning from demonstration (LfD) has become one of the most active research topics in robotics. It encapsulates the robot's perception, learning ability, new skills generation, and adaptability. Compared with the traditional methods, LfD provides a robot-friendly teaching framework, which has given birth to new research directions, enabling robots to interact with people in a social environment. Shaokun Jin, Zhiyang Wang, Yongsheng Ou, and Wei Feng focus on LfD in the point-to-point movement case and propose a learning approach. A set of experiments on the Barrett WAM robot is implemented successfully. This work contributes to the development of LfD of robots.

In addition, the working environment of the robotic manipulator is very complicated. Due to the physical limitations of the control system components, external environmental interference, and safety factors, constraints such as dead-zone input, sector input, and output constraints are inevitably present in the control system. The presence of these factors makes the control design of nonlinear systems more complicated and more difficult. Qi Zhou, Shiyi Zhao, Hongyi Li, Renquan Lu, and Chengwei Wu take the robot manipulator affected by the dead zone input as the research object and introduce an adaptive NN control strategy and successfully apply to the Puma 560 robot manipulator. This article provides a novel idea for adaptive control theory and is significant for tracking control research.

The coordinated control problem of multiple manipulators has attracted more and more attention from researchers. However, compared with single manipulators, theoretical research on multiple manipulators cooperative control systems is still weak. The multiple manipulators cooperative control system is more complicated, especially for trajectory planning problems, collisions, and load distribution of multiple manipulators. For control problems of multiple manipulators in the case of output constraints, Yong Li, Chenguang Yang, Weisheng Yan, Rongxin Cui, and Andy Annamalai propose a novel adaptive NN control where a switching function is introduced to achieve the global stability. Simulations on planar two-link robot manipulators are carried out.

In recent years, the application research of MASs has attracted extensive attention from scholars and produced a large number of excellent research results. However, due to the complexity of MASs, there exist some obstacles and challenges. For the nonaffine nonlinear MASs with actuator faults of partial loss of effectiveness fault and biased fault, Jiahu Qin, Gaosheng Zhang, Wei Xing Zheng, and Yu Kang propose an adaptive NN consensus protocol. Compared with previous works, the input of NNs takes good advantage of both the state information and the consensus error information with an enhanced resolution.

Taking a network of linear systems subject to bounded uncertainties satisfying the matching condition as the research object, in order to solve the distributed event-triggered consensus control problem, Bin Cheng and Zhongkui Li propose a static nonsmooth distributed scalable event-triggered protocol, which does not need any global information of the network graph. This work promotes the development of research on distributed event triggering mechanism, which has important theoretical and practical significance.

Formation control is a hot issue in current MASs research. It refers to a team of multiple agents that maintain a predetermined geometric form (i.e., a formation) while moving toward a particular target or direction as well as adapting to the control of environmental constraints (e.g., avoiding obstacles). Formation control has broad application prospects in various fields, such as military, aerospace, industry, and entertainment. Collaborative formation control technology mainly includes information sensing technology, task allocation technology, track planning technology, and formation control technology. How to solve the leader selection problem is a challenge that needs to be addressed urgently. Lei Xue and Xianghui Cao take second-order MAS as a research object, propose a game theoretical method to address two leader selection problems.

Multisensor fusion algorithm is better than the single sensor fusion algorithm because it can get more data and more information to obtain more accurate and reliable results. Quanbo Ge, Qinmin Yang, and Peng Zhuo address two multisensor observable degree analysis methods and apply them into sensor assignment problems, based on the calculation of nonlinear observability. The sensor algorithm based on the proposed method can be applied for the system that is not fully observable. Moreover, it overcomes the shortcoming of sensor algorithm based on Raccati equation that can only be applied to nonlinear systems. Finally, the simulation results illustrate the feasibility of the proposed multisensor fusion algorithms.

UAVs are becoming more and more widely used in military and civilian applications. In order to make UAVs function better, multiUAV formation flight control is needed to achieve tasks such as coordinated reconnaissance, combat, defense, and spraying of pesticides. At present, the formation flying theory of UAVs has achieved a lot of results, however, the physical flight test can only achieve coordinated formation flight in a simple communication environment. Xiwang Dong, Yangfan Li, Chuang Lu, Guoqiang Hu, Qingdong Li, and Zhang Ren propose a time-varying formation tracking (TVFT) control and successfully implement a flying experiment for three follower quadrotor UAVs enclosing a leader quadrotor UAV.

Trajectory tracking of surface vessels belongs to the dynamic positioning in a broad sense. Specifically, the surface vessel reaches the originally set position through the trajectory tracking control within a prescribed time. Controllers with high-performance trajectory tracking capabilities are required for surface vessels. The control design of surface vessels is challenging. Uncertainty of dynamic models, strong ocean disturbances, under-actuation of models, and incomplete constraints on kinematics are issues that must be addressed. In order to solve the above problems, Shi-Lu Dai, Shude He, Min Wang, and Chengzhi Yuan investigate NN approximators and disturbance observers, subsequently,

develop an adaptive neural control with uncertainty and disturbance compensations.

The aforementioned sections have briefly demonstrated 14 articles related to our special issue. The Guest Editors appreciate all of the authors' contributions to this special issue and thank them for sharing the breakthrough results with us. Finally, they want to show our respect to the reviewers for their great effort and strong support!

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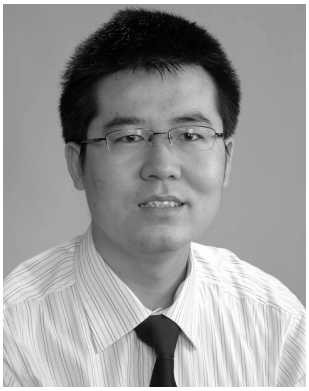

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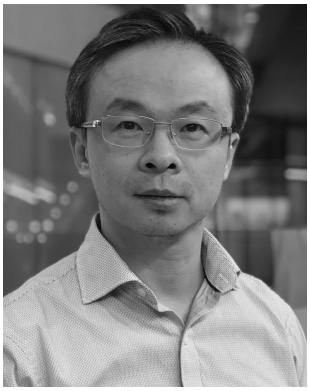

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